User-Centered Design of Spacecraft Ground Data Systems at NASA's Goddard Space Flight Center

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Reason for Paper

- **Little presence at space conferences**
- **Chance get together**
- **Share knowledge and lessons learned**

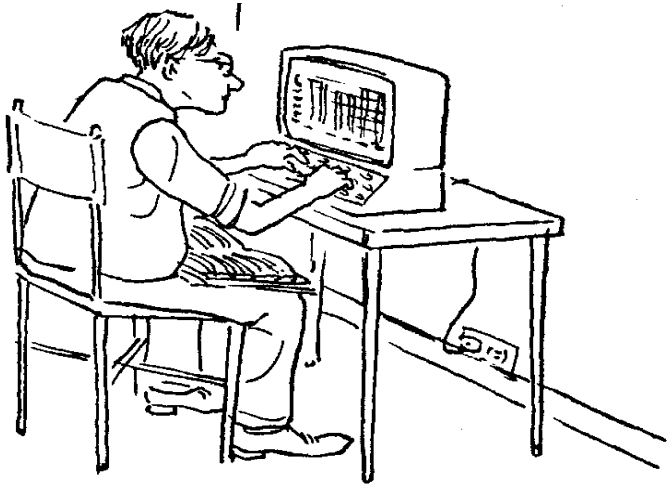
Agenda

- **Background on UCD**
- **Techniques used at NASA/GSFC**

User-Centered Design

- **What is It?**
  - **Interdisciplinary technical field concerned with the capabilities and limitations of humans in the design and use of tools, equipment, systems, and environments.**
- **Objective:**
  - **Optimize overall system performance by taking into account the people who are going to use, operate, and maintain it.**

….Designing systems as if people mattered PNNL



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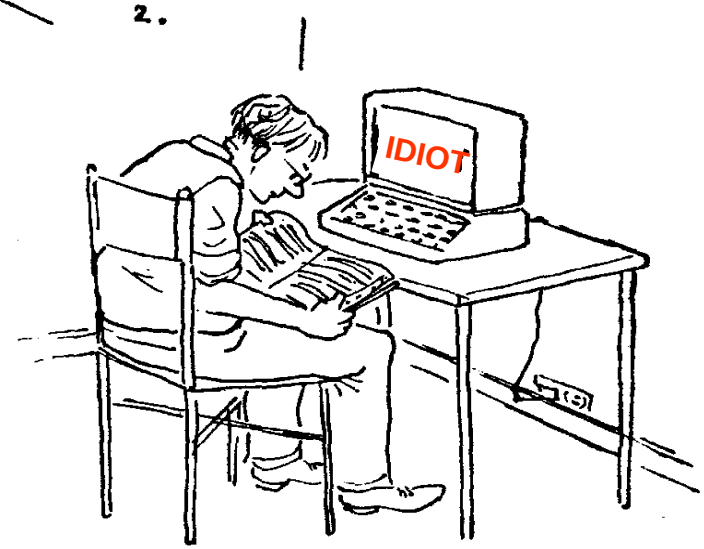

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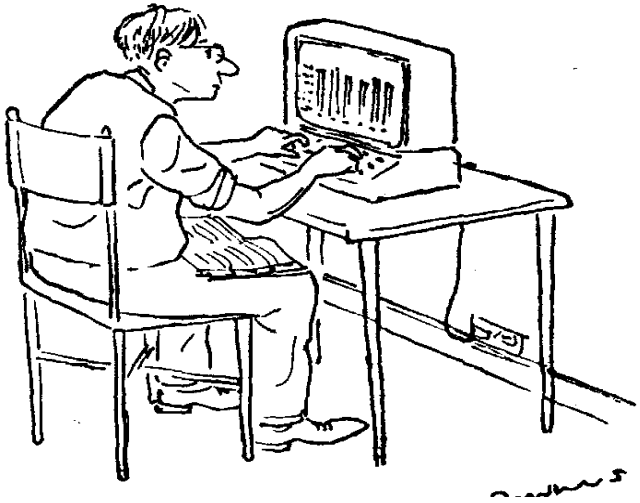
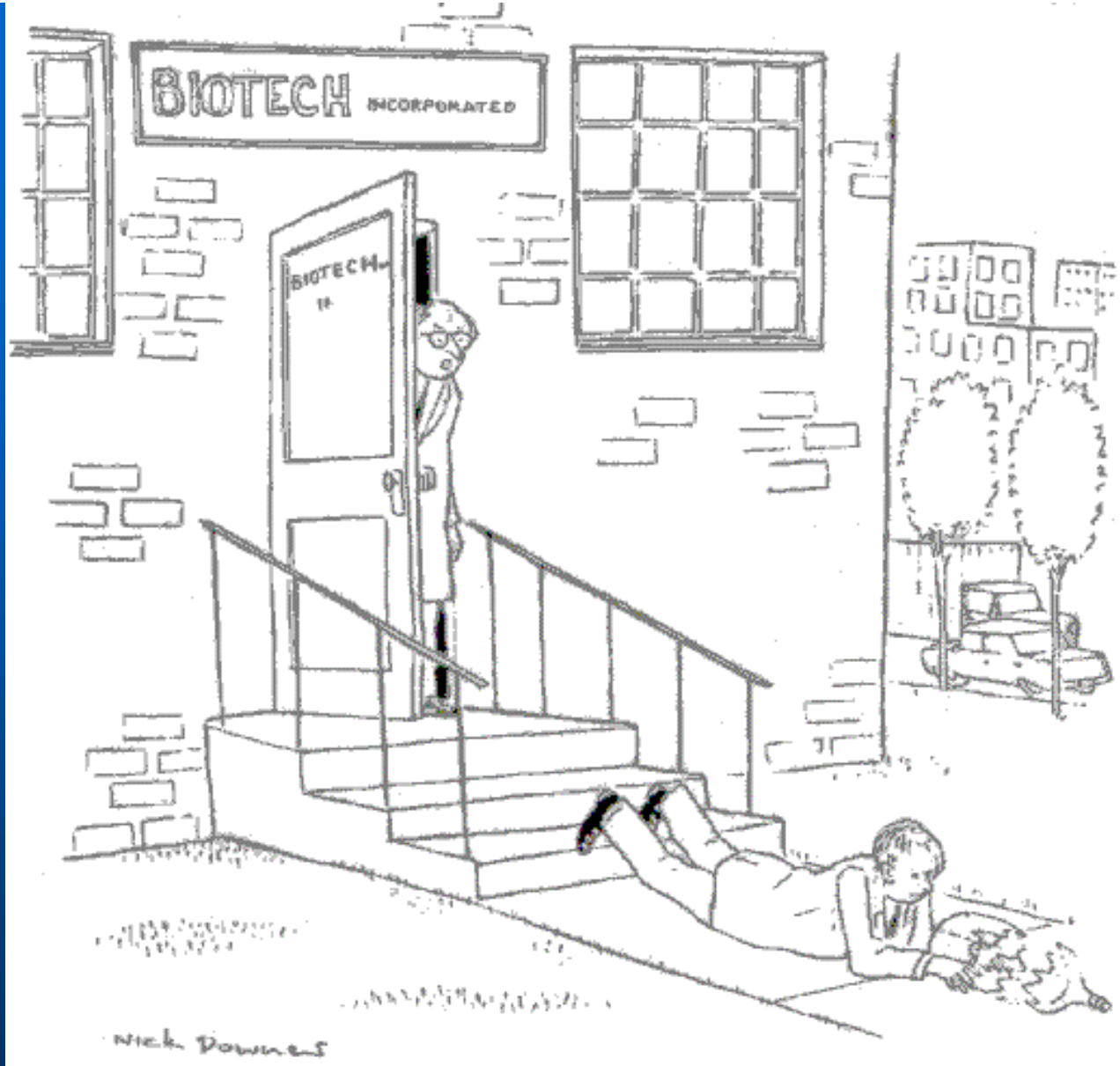


“Usability” of a System

- Time to learn
- Speed of performance
- Rate of errors by users
- Retention over time
- Subjective satisfaction

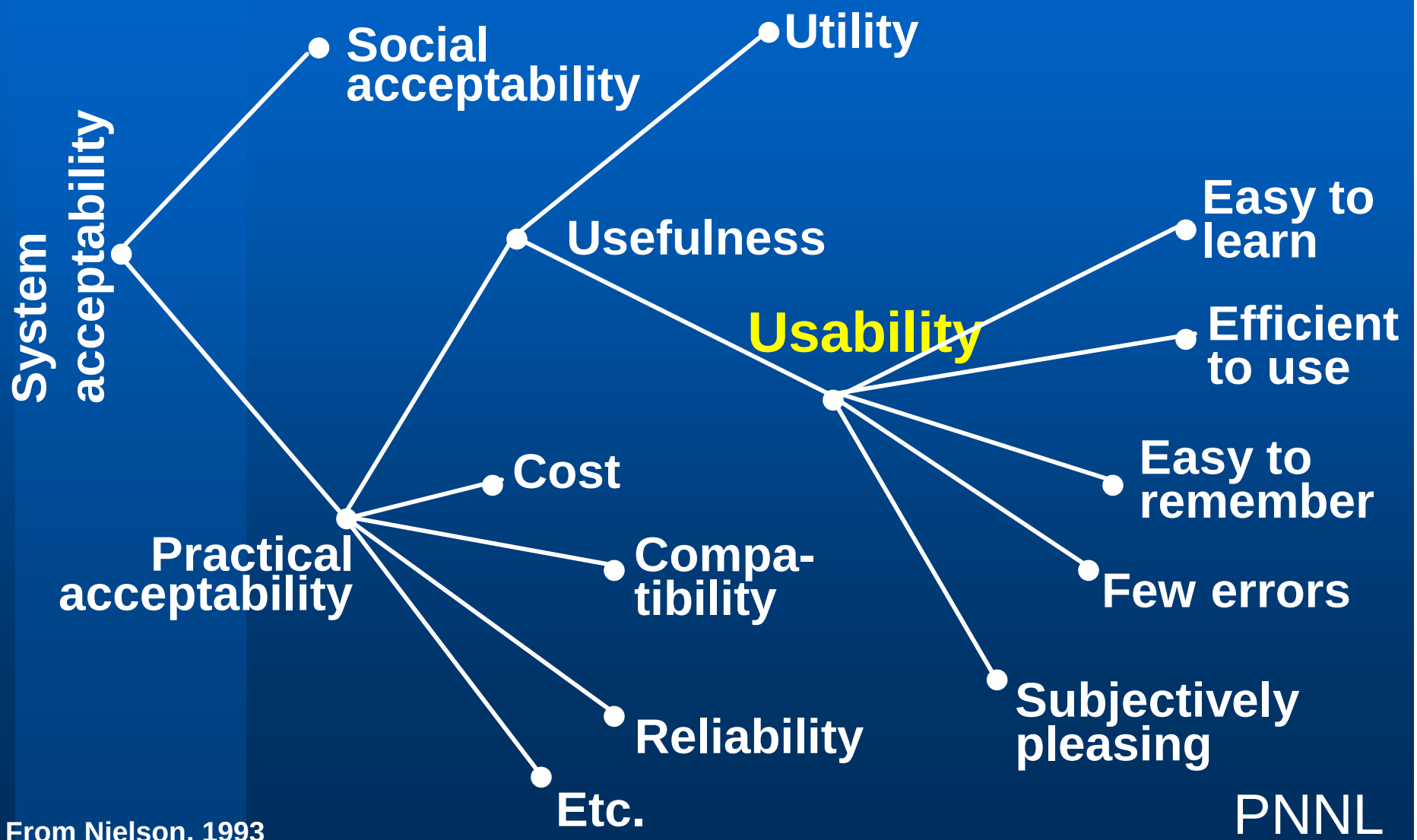
“Human Error”

- **Really hiding…**
  - **Inadequate training**
  - **False appearance or lack of indication that something is wrong**
  - **Design defect not allowing for operator’s limitations**
  - **Non-fault-tolerant system design (small human error spirals out of control)**



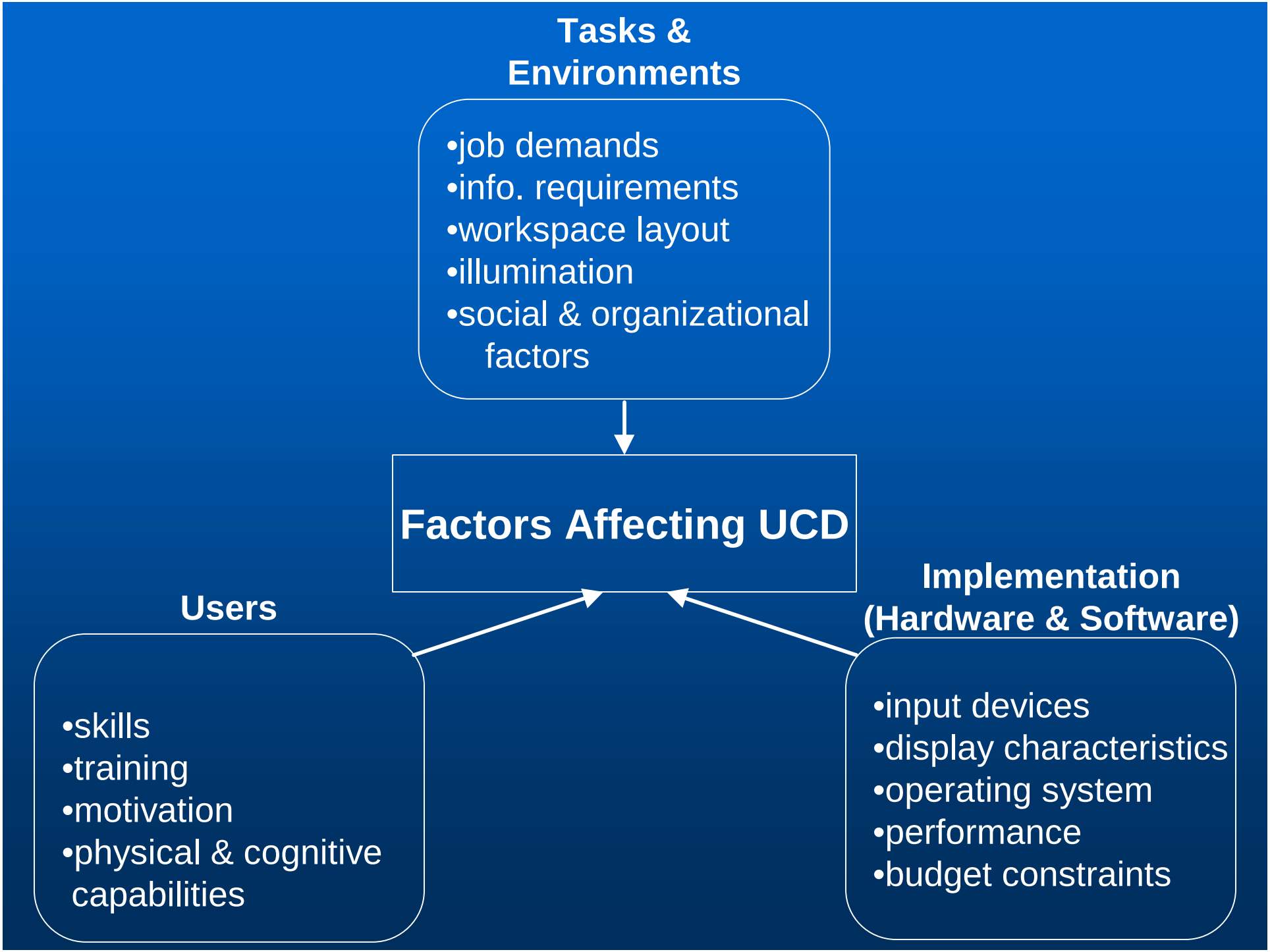
"Darn it, Hawkins, when handling genetically engineered microbes, that's just the sort of thing one tries to avoid!"

Attributes of System Acceptability



From Nielson, 1993

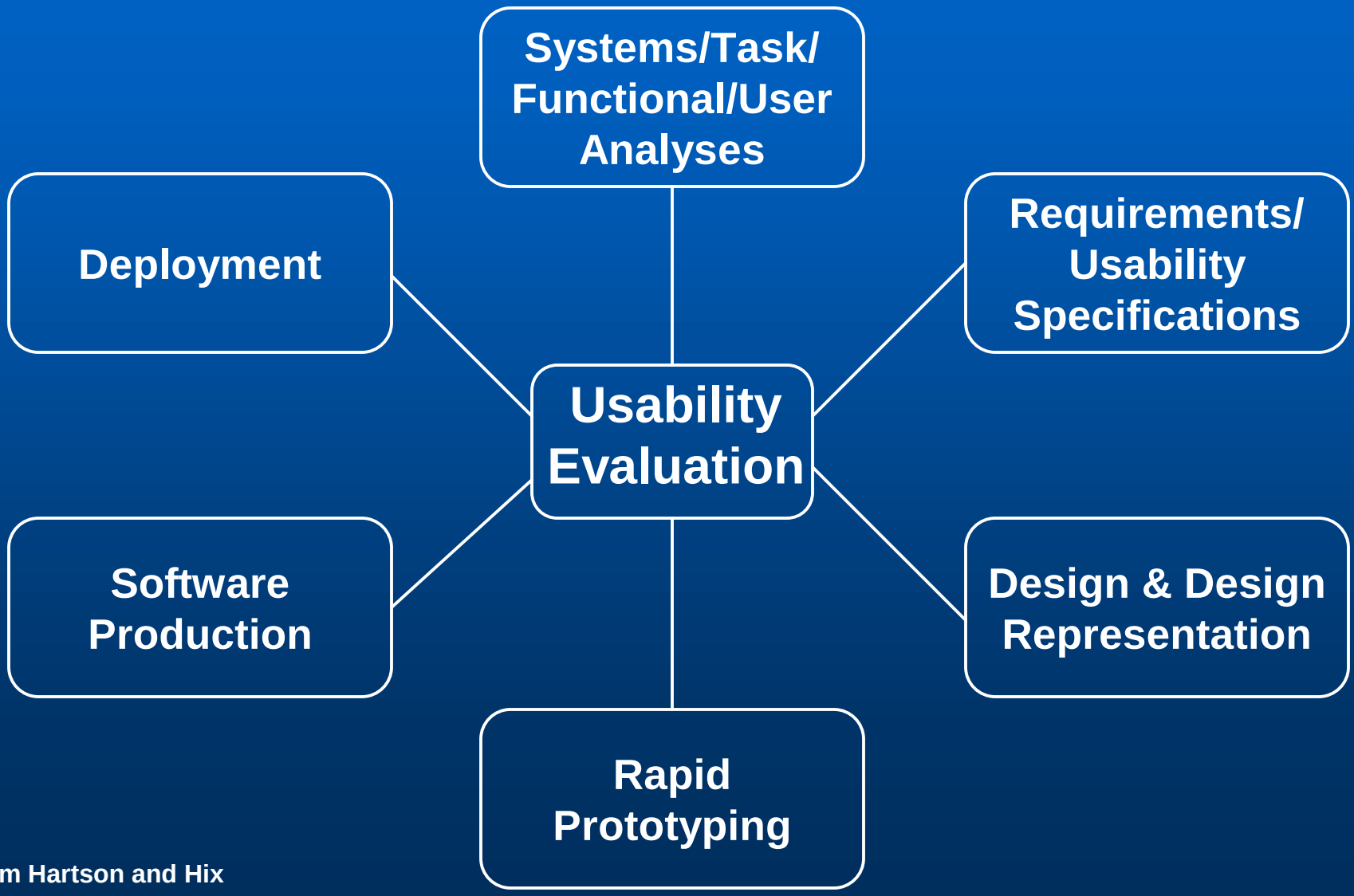
PNNL


Tasks &
Environments
•job demands
•info. requirements
•workspace layout
•illumination
•social & organizational
factors
Factors Affecting UCD
Users
•skills
•training
•motivation
•physical & cognitive
capabilities
Implementation
(Hardware & Software)
•input devices
•display characteristics
•operating system
•performance
•budget constraints

UCD -- Product & Process

- **Product**
  - **Content**
  - **Style**
  - **Directly affects usability**
- **Process**
  - **Environment in which interfaces are built**
  - **Techniques and tools**
  - **Affects ability to provide usability**

Support Throughout Full Life Cycle



*From Hartson and Hix

Techniques at NASA-GSFC

- User design working (focus) groups
- Cognitive modeling
- Education of software designers
- Expert evaluations
- Human - software agent interaction
- Rapid software prototyping
- Scenario-based design
- Task analysis
- Usability testing
- User interface guidelines, style guides and standards
- Workstation and control room design

Paper

- **Techniques for software design**
  - **Cognitive & mental models**
  - **Rapid prototyping**
  - **Usability testing**
- **References**

Presentation

- **Techniques**
  - **Scenario-based design**
  - **Rapid prototyping**
- **Projects**
  - **VMOC/SERS**
  - **EOSDIS**

VMOC

Virtual Mission Operations Center

- **Goal: To work with mission operations staff to develop the future technology and workgroup computing concepts that will be needed to meet the new ground rules for mission operations.**

- **Objectives: Demonstrate, evaluate, and integrate advanced technologies which**
  - **Increase operator efficiency**
  - **Minimize use of dedicated resources**

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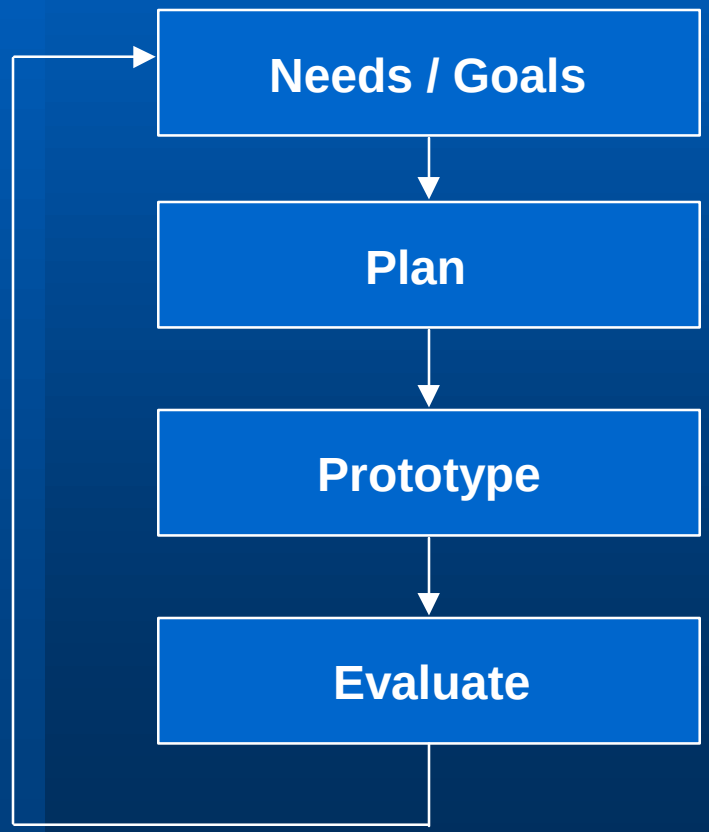
New Ops Concepts

- **"Traditional" operations**
  - **7 x 24 support**
  - **Unique and dedicated resources**
- **"Lights-Out" environment**
  - **No team member or just 1, 5x8**
  - **On-call SCT**
  - **Multi-mission support**

Design Philosophy

- **Technology exploration via prototyping and user-centered design**



Use a ‘design-build-test-revise’ process

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UCD at Stages of Life Cycle

- Concept Definition
  - Task analyses
  - Steering Committee
  - Composition graphing
  - Scenario-based design
  - Conceptual prototyping
- Proof-of-Concept
  - Scenario-based design
  - Cooperative prototyping
- Development
  - Cooperative prototyping
  - Usability testing
- Operations
  - Usability testing

Scenarios

- **A narrative description of what people do and experience as they try to make use of computer systems and applications**
- **Elements**
  - **Identifies the person as having certain motivations**
  - **describes actions taken and reasons**
  - **characterizes results**

Scenario-Based Design

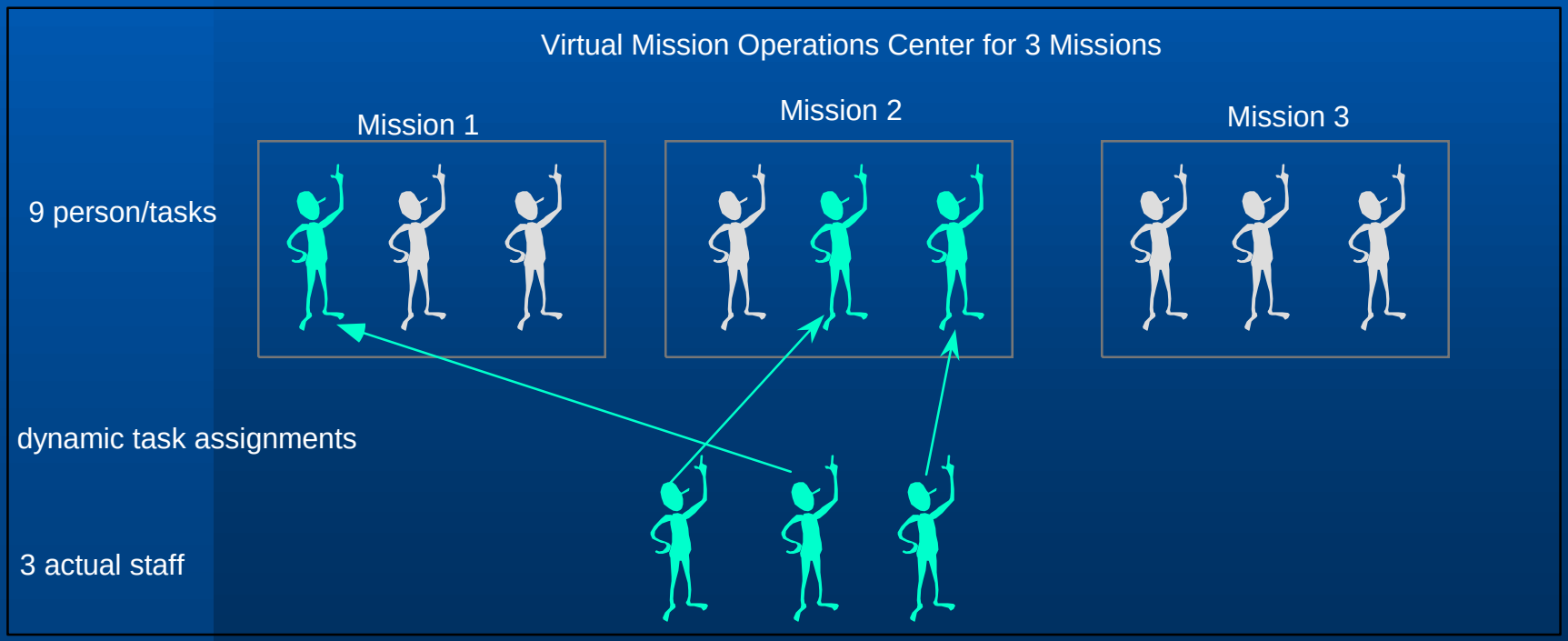
- Goals
  - A more concrete representation of how the system would operate
  - Basis for communication among the members of the design team, the client, and the end users
  - A starting point for the follow-on prototyping effort.

Scenarios

- **Forms**
  - **Storyboards**
  - **Annotated cartoon panels**
  - **Video mockups**
  - **Scripted prototypes**

Concept of Virtual Operations

- **People and resources are mapped according to skills, experience, and availability to meet the needs of a multiple mission, distributed, operations facility. They can be distributed, and may join in ad hoc groups to meet the occasional peak demands.**



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Scenarios

- **Three Scenarios**
  - **Simple (basic management by exception)**
  - **Moderate (distributed management by exception)**
  - **Complex (dynamic distributed management by exception)**
- **Descriptions**
  - **Text**
  - **Matrix**

Text Descriptions

- **Title**
  - Basic management by exception (routine monitoring)
- **Objects**
  - Creating a pass plan, distributed management
- **Background**
  - For the basic management by exception mode of operations, a centrally located operator defines a set of exceptions for the various system elements
- **Specifics (Details)**
  - The scenario begins with the VMOC operator building a pass plan. To build or modify a pass plan, the VMOC operator must first log into the advanced planning mode of the software

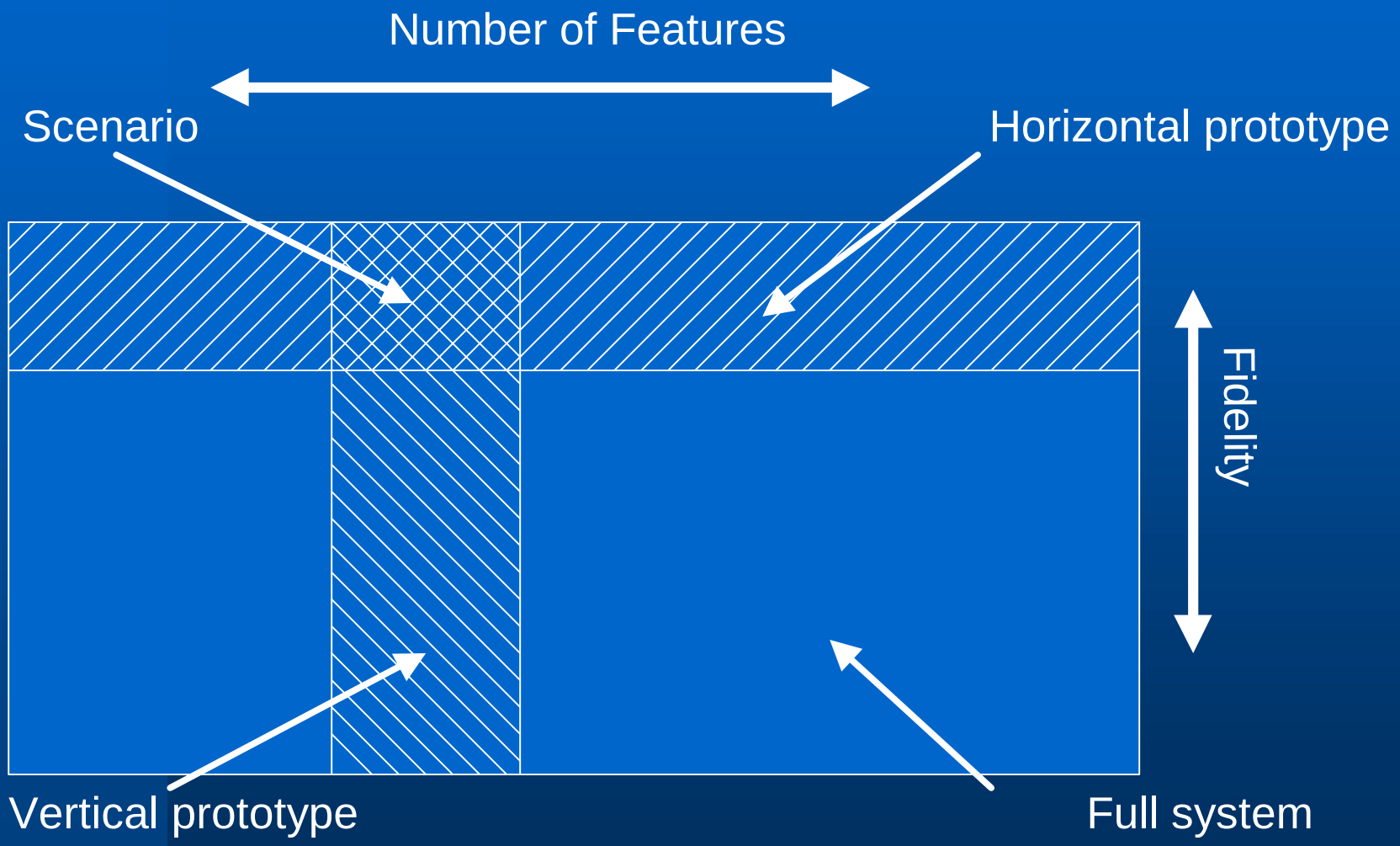
Scenario Matrix

SCENARIO 1			
Activities	**Tasks**	**Action by: Autonomous (A) Operator (O) Engineer (E)**	**Build # 1, 2, 3 Simulated (S) Future build (F)**
• Off-line activities	Open appropriate pass plan	O	1
	Translate activity requests into pass plan	A	1 (S)
	View and edit graphical pass plan	O	1
	Assign emergency support person	O	1 -- change pass plan 2 -- use team building tool to assign support
	Notify person of assignment	A	3
	Set plan to automatic execute mode	O	1
	Check rules for pass plan commands	A	2
	Save pass plan	O	1

Software Rapid Prototyping

- **Types**
  - **Throwaway**
  - **Evolving**
- **Goals**
  - **Gain a better understanding of the users' needs**
  - **Allow the developer to confirm that a specific approach will accomplish the needed functions with adequate system performance**

Dimensions of Prototyping



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	Save pass plan	O	1

Techniques of Prototyping

- **Conceptual prototyping**

  Use a series of iterative, evolving prototypes to

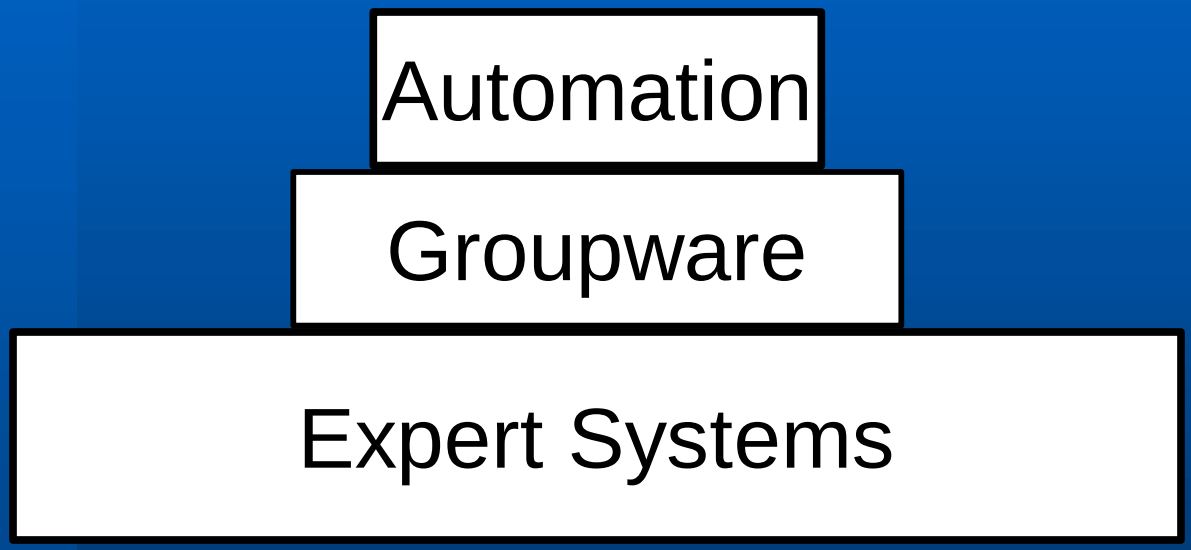
  - **Implement basic concepts,**
  - **Demonstrate each prototype to users**
  - **Produce a prototype that can be used as a foundation for further development**

- **Cooperative prototyping**
  - **Operational VMOC prototyping**
  - **Technology exploration**

Initial VMOC Results

- **Highest payoff is in automated routine tasks**
- **New focus on reducing workload and cooperative tasks**

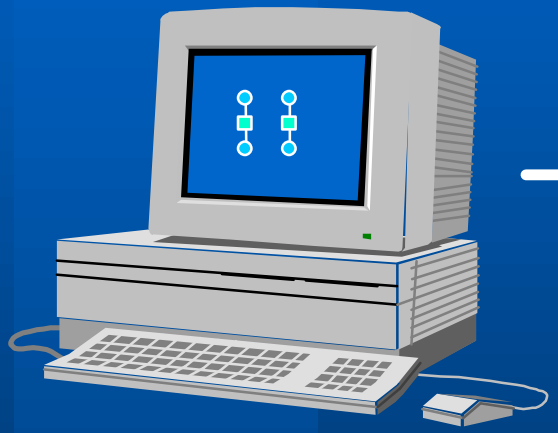
First Attempt



Obstacles to Light-Out Ops

- **Must Be Sure:**
  - **Spacecraft Is Healthy**
  - **Networks Are Up**
- **Too Much Paperwork**
  - **Anomaly Reports, Pass Plans, Pass Summaries…**
- **Need to Communicate with Distributed Team**

G2/IMT Development Environment



IMT
Satellite control toolkit

G2

Real-time process control expert system

- **SYBASE**
- **DB gateway**
- **Front-end processor gateway**

Unix, X-Windows, TCP/IP

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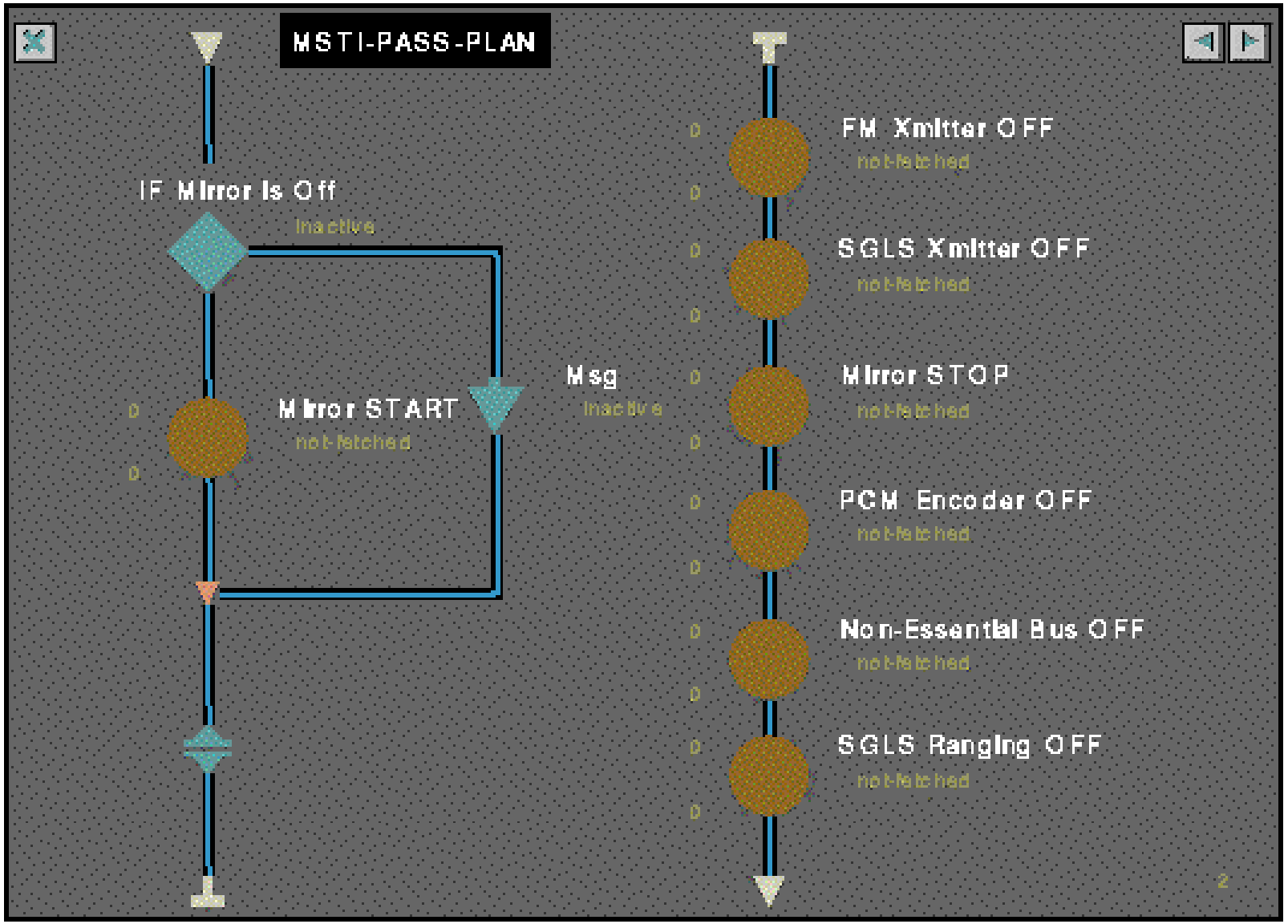
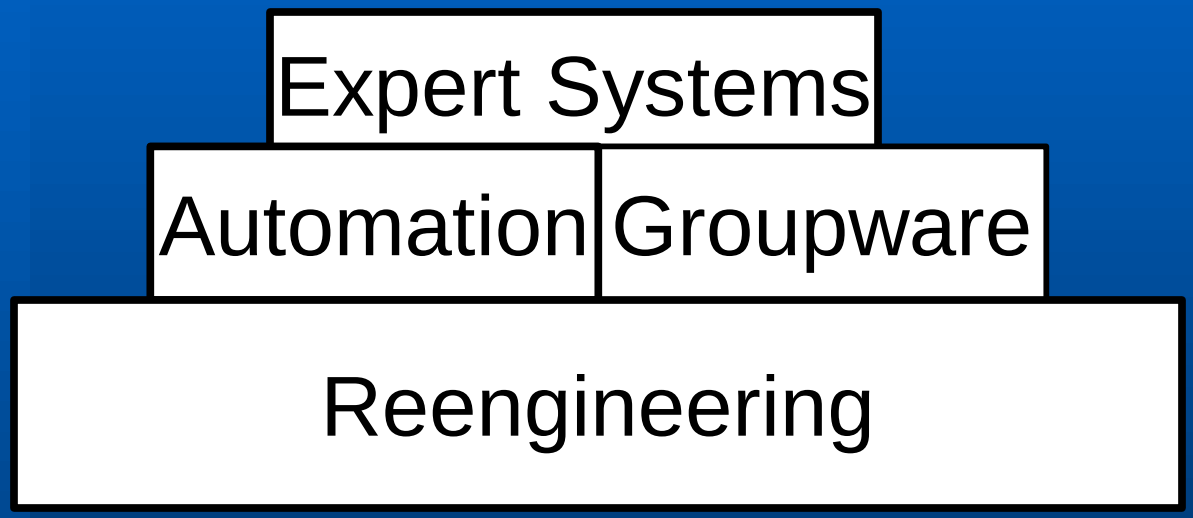
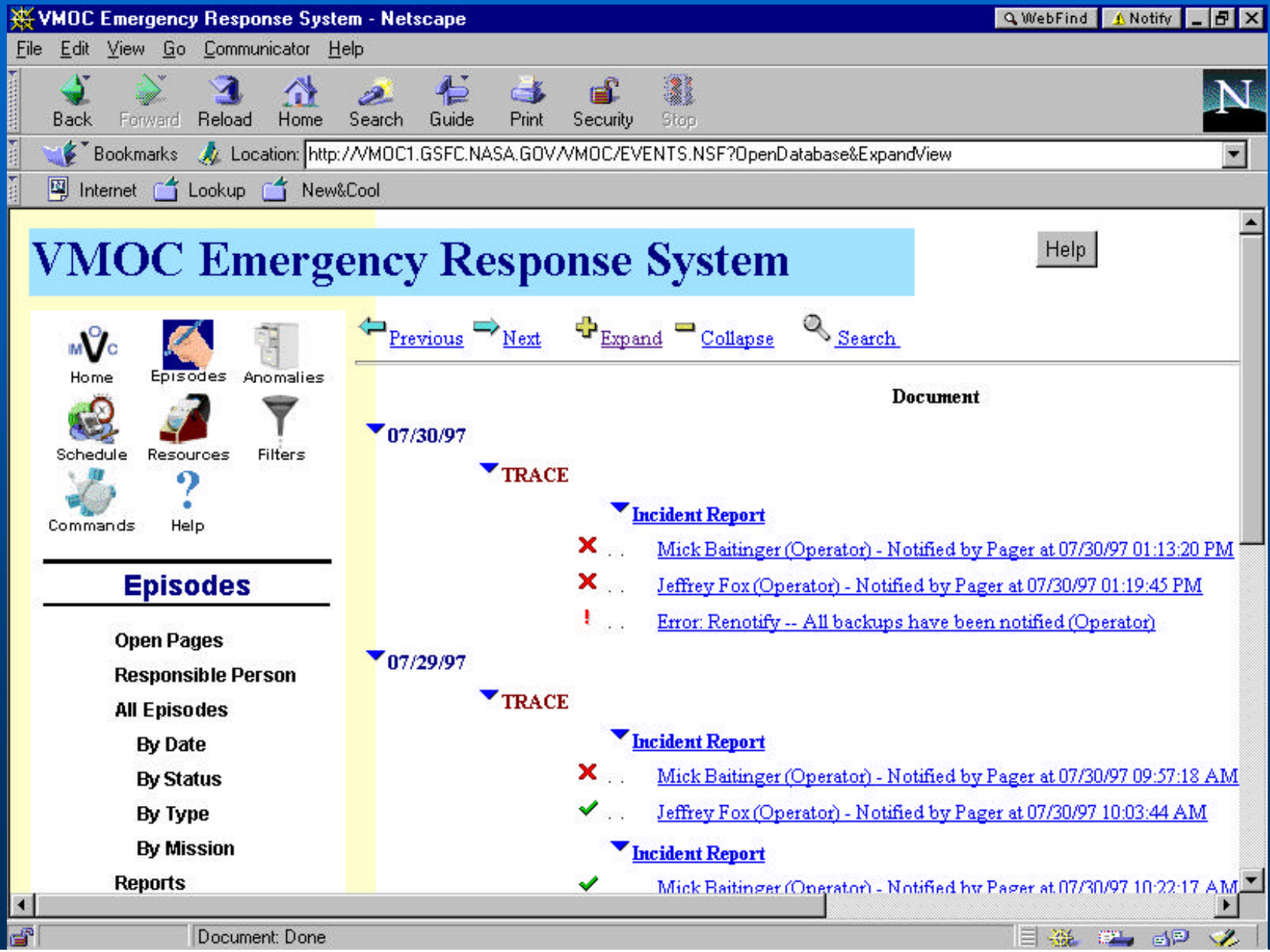
IMT Pass Plan

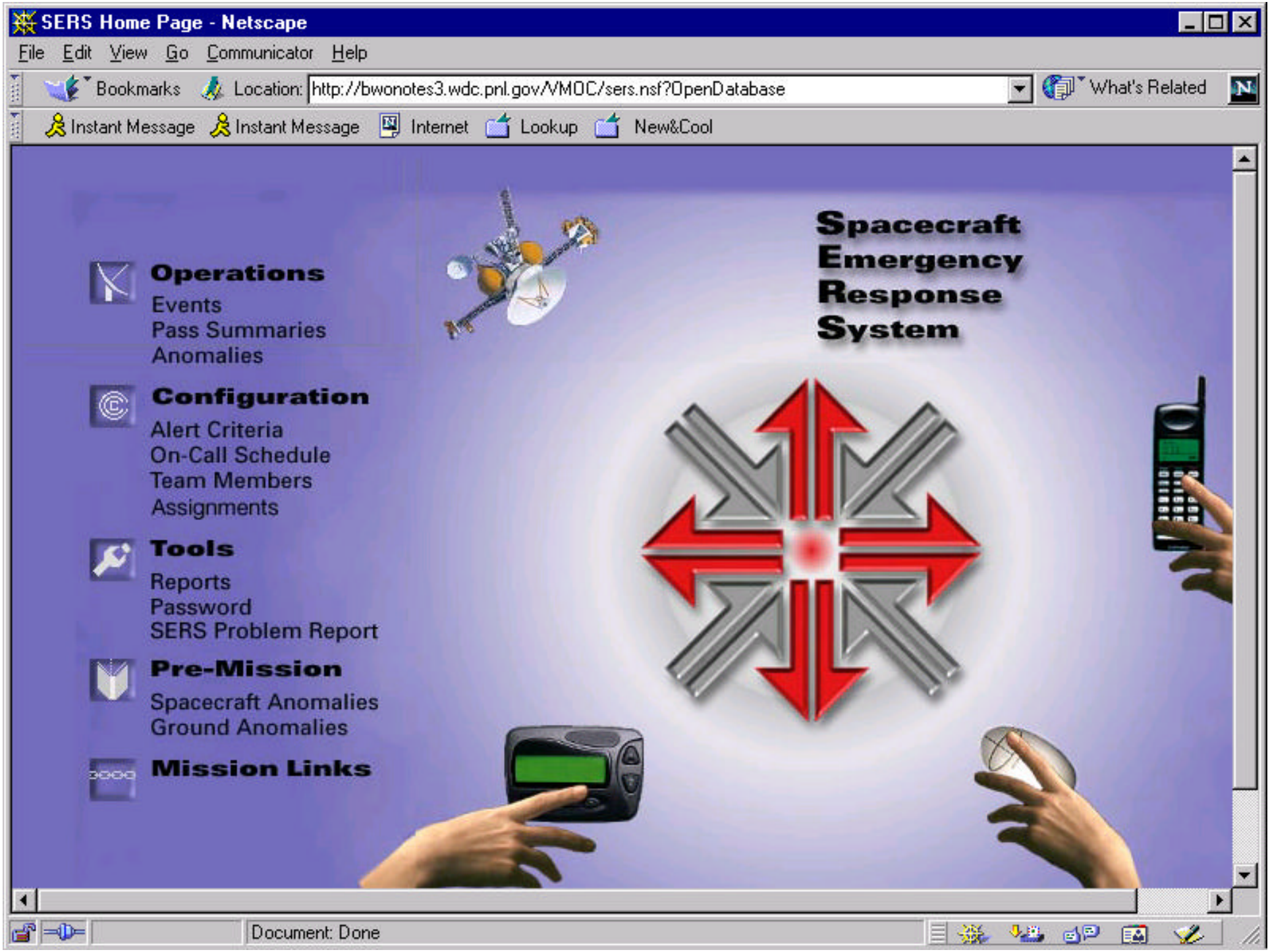


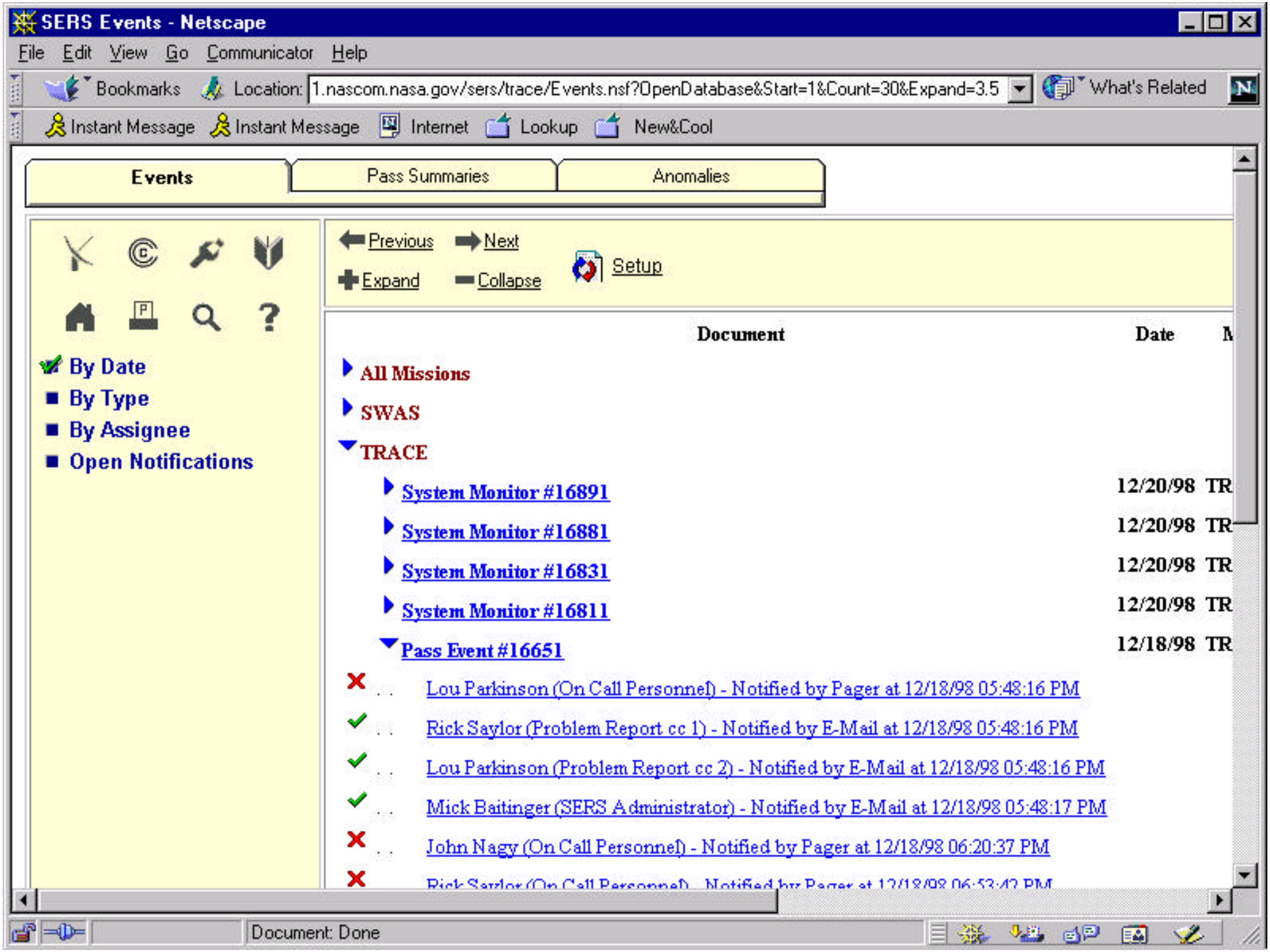
Second Attempt



First Web Design




SERS Home Page - Netscape
File Edit View Go Communicator Help
Bookmarks Location: http://bwonotes3.wdc.pnl.gov/VMOC/sers.nsf?OpenDatabase
What's Related
Instant Message Instant Message Internet Lookup New&Cool
Spacecraft Emergency Response System
Operations
Events
Pass Summaries
Anomalies
Configuration
Alert Criteria
On-Call Schedule
Team Members
Assignments
Tools
Reports
Password
SERS Problem Report
Pre-Mission
Spacecraft Anomalies
Ground Anomalies
Mission Links
Document: Done


SERS Events - Netscape
File Edit View Go Communicator Help
Bookmarks Location: 1.nascom.nasa.gov/sers/trace/Events.nsf?OpenDatabase&Start=1&Count=30&Expand=3.5 What's Related
Instant Message Instant Message Internet Lookup New&Cool
Events
Pass Summaries
Anomalies
By Date
By Type
By Assignee
Open Notifications
Previous
Next
Expand
Collapse
Setup
Document
Date
All Missions
SWAS
TRACE
System Monitor #16891 12/20/98 TR
System Monitor #16881 12/20/98 TR
System Monitor #16831 12/20/98 TR
System Monitor #16811 12/20/98 TR
Pass Event #16651 12/18/98 TR
Lou Parkinson (On Call Personnel) - Notified by Pager at 12/18/98 05:48:16 PM
Rick Saylor (Problem Report cc 1) - Notified by E-Mail at 12/18/98 05:48:16 PM
Lou Parkinson (Problem Report cc 2) - Notified by E-Mail at 12/18/98 05:48:16 PM
Mick Baitinger (SERS Administrator) - Notified by E-Mail at 12/18/98 05:48:17 PM
John Nagy (On Call Personnel) - Notified by Pager at 12/18/98 06:20:37 PM
Document: Done

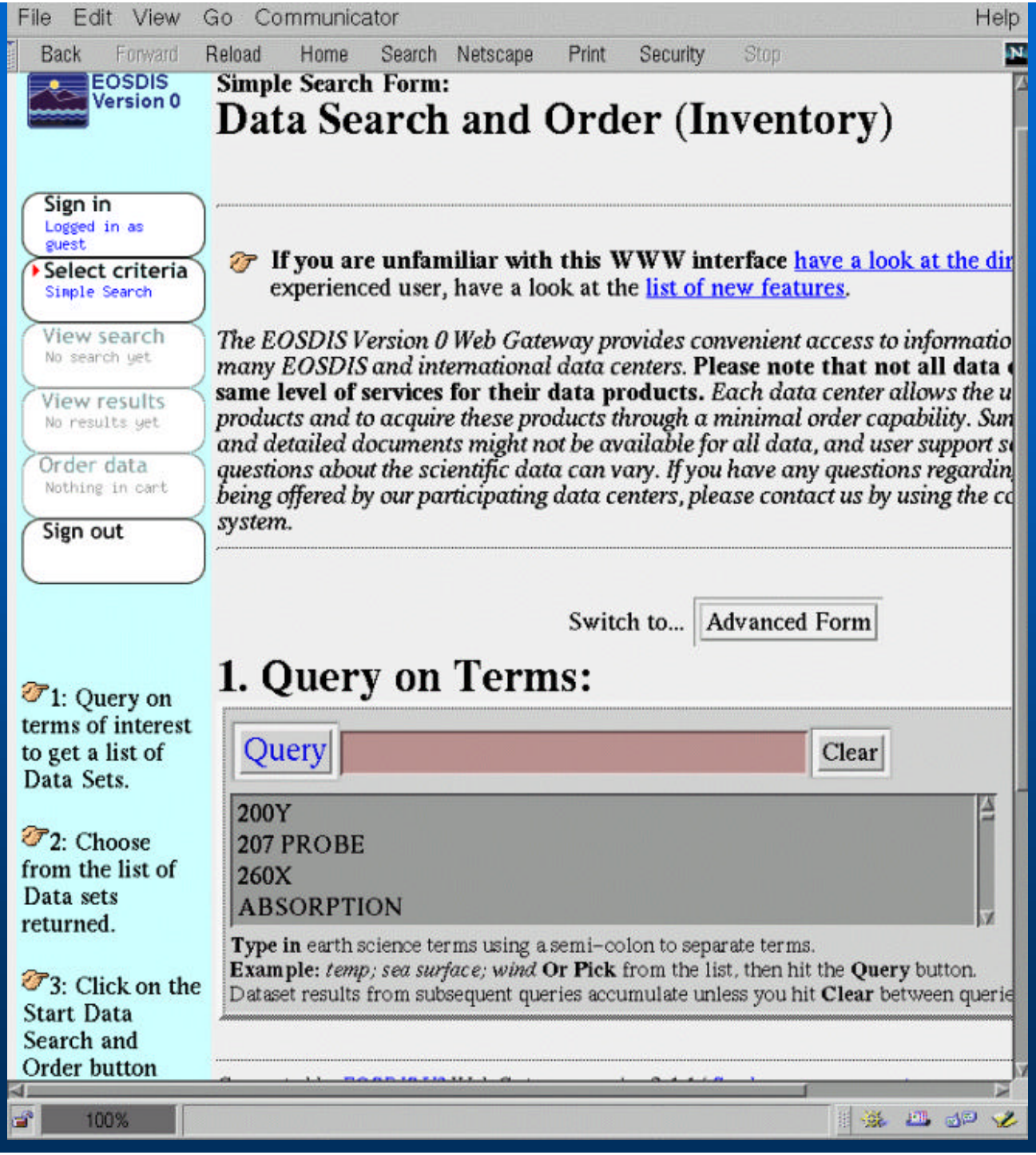
EOSDIS Protoyping

- **Function**
  - **Search EOS and related data in archives distributed all over the world (15 archives, 10 US and 5 international including Canada, Russia, Australia, Germany and Japan), from a single user interface.**
- **Conceptual prototypes**
  - **R1 Character-based**
  - **R2 Motif Windows**

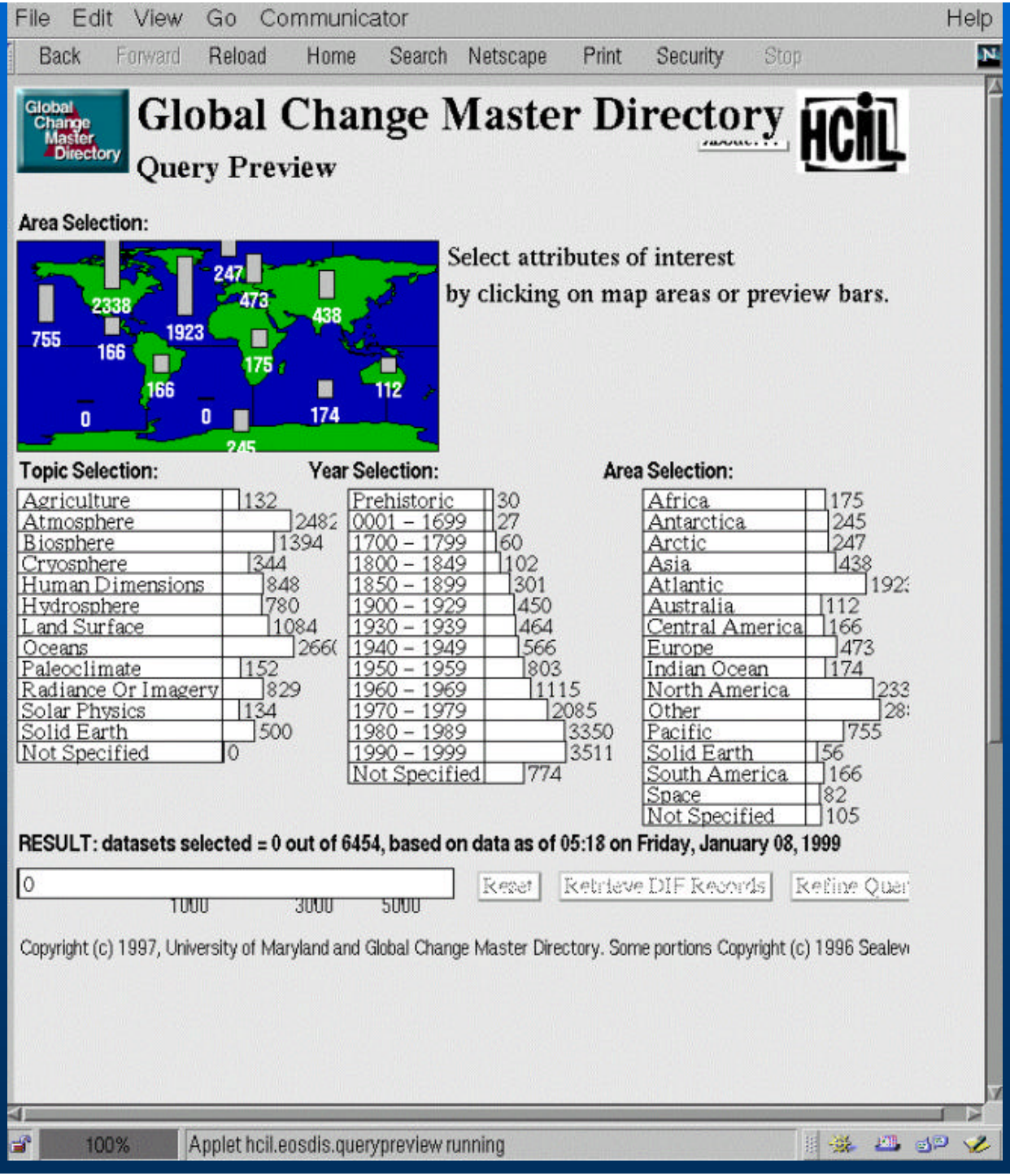
R3


File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
2. Build your search...
This is where you'll add/modify your search criteria. The Edit button for each search attribute will ta
editing that attribute (the icon will do this too). You can also Delete all the criteria for that attribute.
You haven't specified enough search attributes to start your search.
You will need to add a parameter, sensor, or data set to be able to start your search.
Help
Comments
Check Order Status
User Preferences
User Support
Minimum requirements for Data Search and Order (Inventory): (1) At least one of
parameter, or sensor. (2) A geographic region: selecting as small a region as possible i
Geographic Region
Edit Delete Help
RANGE:
90.0000° to -90.0000° Lat
-180.0000° to 180.0000° Lon
-180 -120 -60 0
90 60 30 0 -30 -60 -90
-180 -120 -60 0
The following search criteria are interdependent: constraining any one of them (like Sensor) may lim
another one (like Parameter). A "*" indicates that a choice has become incompatible with more-recer
Parameter
(A physical property being measured in the data (e.g., h
Data Set
(A named collection of data/observations.)
Sensor
(An instrument used in gathering the data.)
Data Center
(The place where the data are archived.)
Source
(The spacecraft, airplane, etc. the sensor was located on
Campaign
(The project or study that obtained the data.)
Processing Level
(Amount of processing performed on the data (e.g., 0 =
No extended search criteria are available.
100%

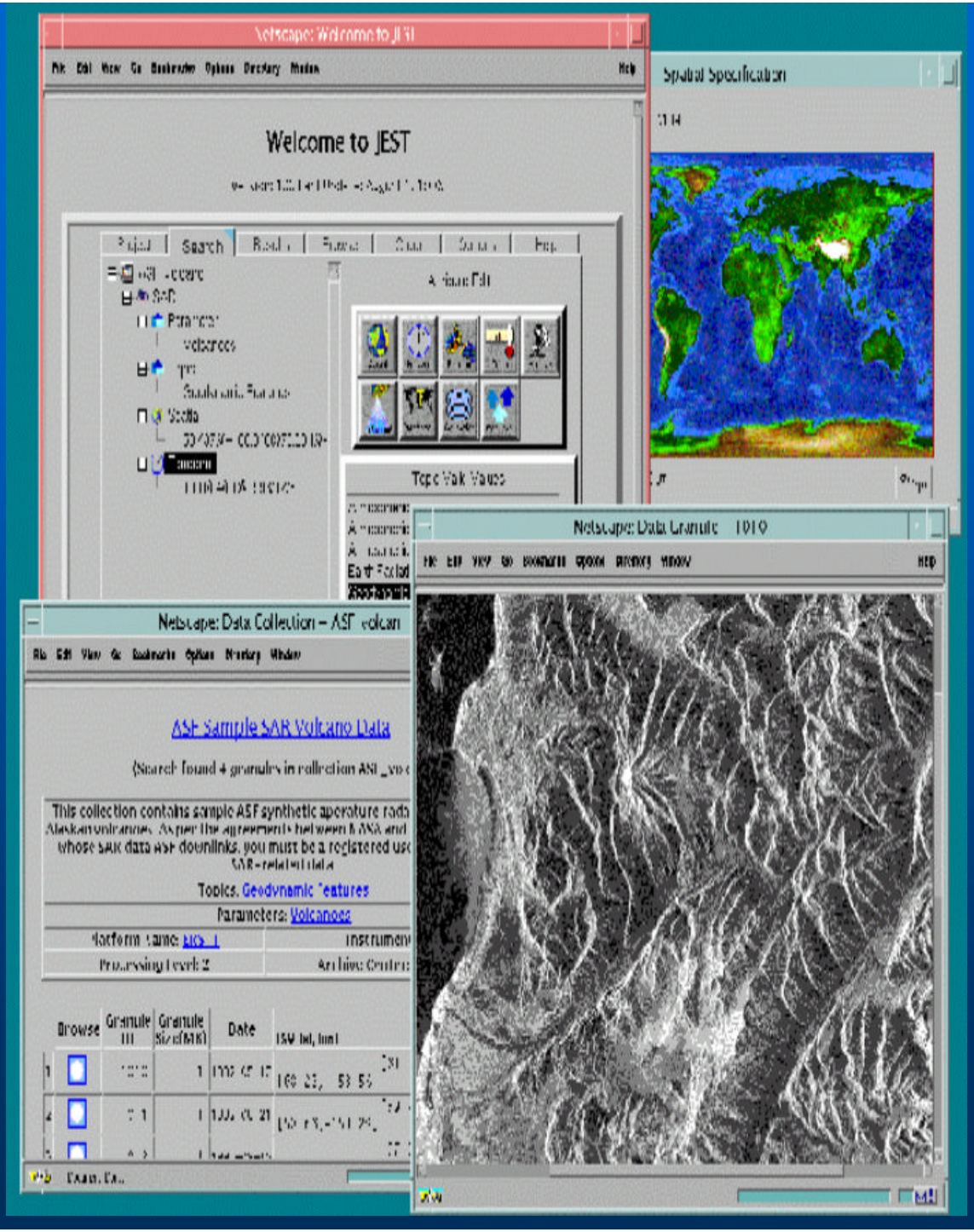
R4


File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
EOSDIS Version 0
Simple Search Form:
Data Search and Order (Inventory)
Sign in
Logged in as guest
Select criteria
Simple Search
View search
No search yet
View results
No results yet
Order data
Nothing in cart
Sign out
If you are unfamiliar with this WWW interface have a look at the dir
experienced user, have a look at the list of new features.
The EOSDIS Version 0 Web Gateway provides convenient access to informatio
many EOSDIS and international data centers. Please note that not all data
same level of services for their data products. Each data center allows the u
products and to acquire these products through a minimal order capability. Sun
and detailed documents might not be available for all data, and user support s
questions about the scientific data can vary. If you have any questions regardin
being offered by our participating data centers, please contact us by using the c
system.
Switch to... Advanced Form
1. Query on Terms:
1: Query on terms of interest to get a list of Data Sets.
2: Choose from the list of Data sets returned.
3: Click on the Start Data Search and Order button
Query
Clear
200Y
207 PROBE
260X
ABSORPTION
Type in earth science terms using a semi-colon to separate terms.
Example: temp; sea surface; wind Or Pick from the list, then hit the Query button.
Dataset results from subsequent queries accumulate unless you hit Clear between queri
100%

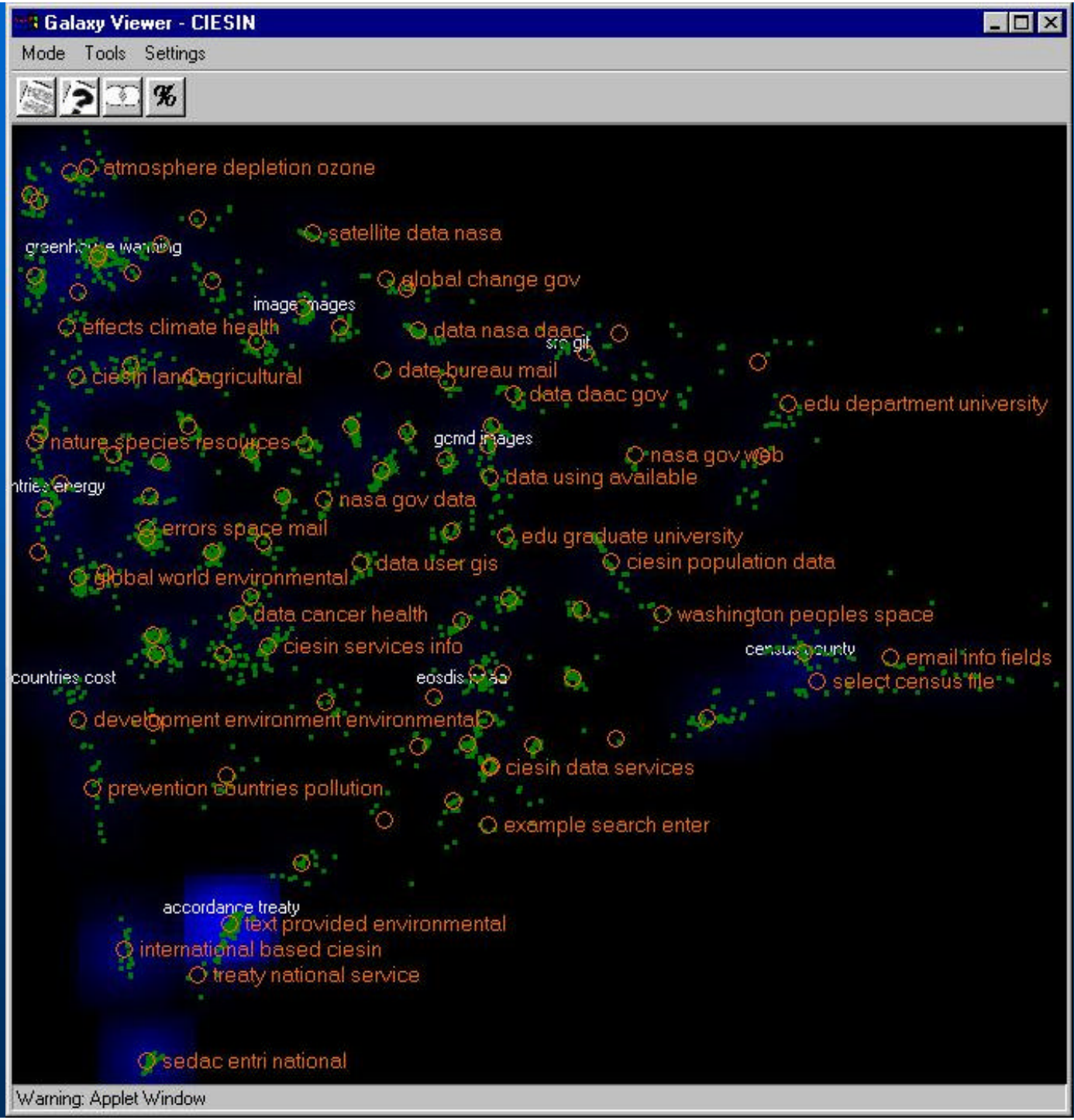
R5


File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
Global Change Master Directory
Global Change Master Directory
Query Preview
HCIL
Area Selection:
247
2338
473
438
755
1923
166
175
166
112
0
0
174
245
Select attributes of interest
by clicking on map areas or preview bars.
Topic Selection:
Agriculture 132
Atmosphere 2482
Biosphere 1394
Cryosphere 344
Human Dimensions 848
Hydrosphere 780
Land Surface 1084
Oceans 2660
Paleoclimate 152
Radiance Or Imagery 829
Solar Physics 134
Solid Earth 500
Not Specified 0
Year Selection:
Prehistoric 30
0001 – 1699 27
1700 – 1799 60
1800 – 1849 102
1850 – 1899 301
1900 – 1929 450
1930 – 1939 464
1940 – 1949 566
1950 – 1959 803
1960 – 1969 1115
1970 – 1979 2085
1980 – 1989 3350
1990 – 1999 3511
Not Specified 774
Area Selection:
Africa 175
Antarctica 245
Arctic 247
Asia 438
Atlantic 192
Australia 112
Central America 166
Europe 473
Indian Ocean 174
North America 233
Other 28
Pacific 755
Solid Earth 56
South America 166
Space 82
Not Specified 105
RESULT: datasets selected = 0 out of 6454, based on data as of 05:18 on Friday, January 08, 1999
0
1000
3000
5000
Reset
Retrieve DIF Records
Refine Quer
Copyright (c) 1997, University of Maryland and Global Change Master Directory. Some portions Copyright (c) 1996 Sealev
100%
Applet hcil.eosdis.querypreview running

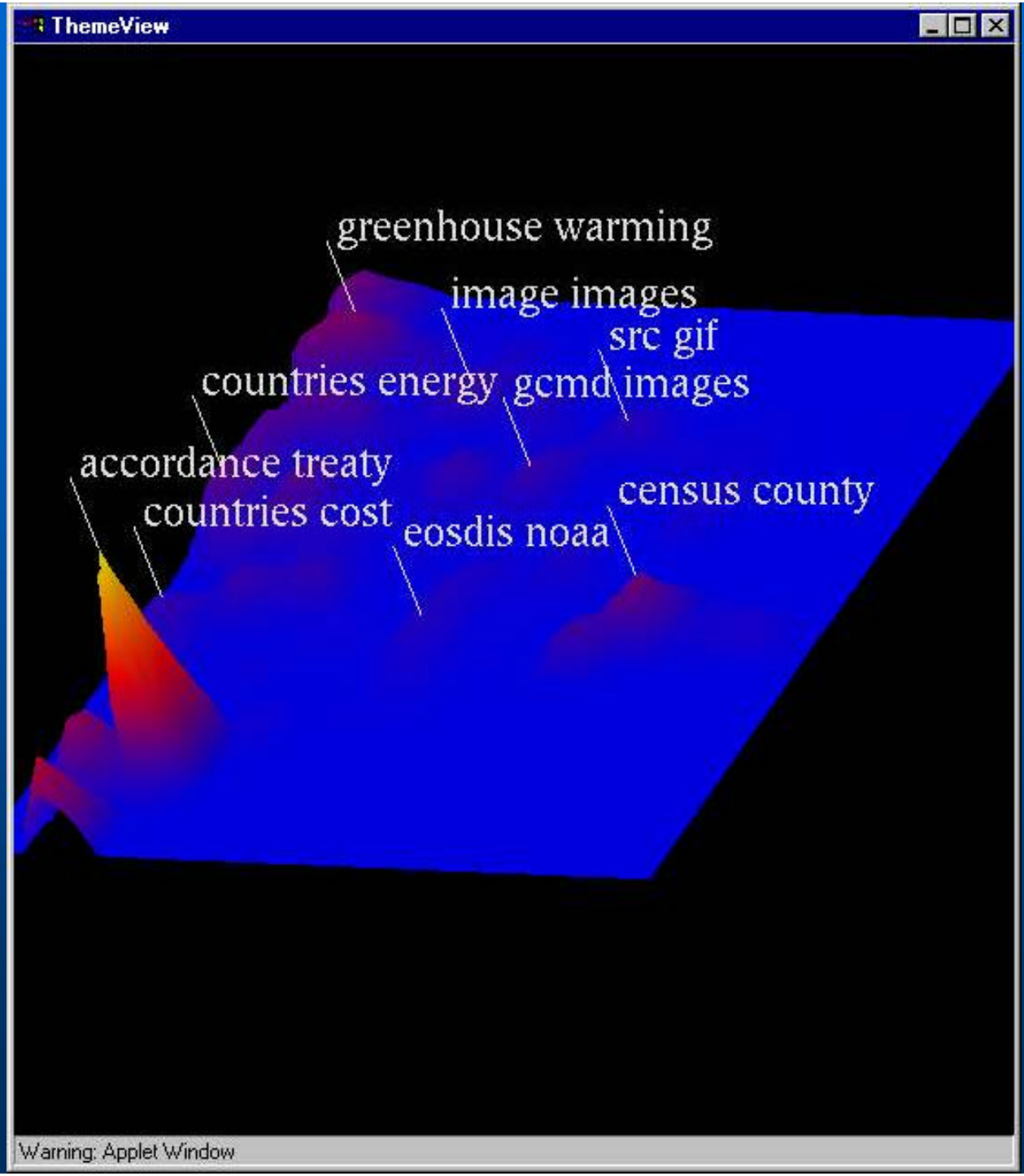
R6


Welcome to JEST
Spatial Specification
Netscape: Data Granule
Netscape: Data Collection – ASF volcan
ASF Sample SAR Volcano Data
Browse
Granule
Granule Size(MB)
Date

RX


Galaxy Viewer - CIESIN
Mode
Tools
Settings
atmosphere depletion ozone
satellite data nasa
global change gov
effects climate health
data nasa daac
ciesin land agricultural
date bureau mail
data daac gov
edu department university
nature species resources
gcmd images
nasa gov web
data using available
nasa gov data
errors space mail
edu graduate university
data user gis
ciesin population data
global world environmental
data cancer health
washington peoples space
ciesin services info
email info fields
select census file
countries cost
development environment environmental
ciesin data services
prevention countries pollution
example search enter
accordance treaty
text provided environmental
international based ciesin
treaty national service
sedac entri national
Warning: Applet Window

Rx


ThemeView
greenhouse warming
image images
src gif
countries energy
gcmd images
accordance treaty
census county
countries cost
eosdis noaa
Warning: Applet Window

Conclusions

- **There are many User-Centered Design techniques**
- **Each human factors technique is useful**
  - **No cookie cutter formula**
- **Highest impact on program**
  - **Early focus on the users**
  - **Users are involved throughout design**